CERTIFIED HEALTH & NUTRITION COUNSELOR ONLINE COURSE - SESSION 11:

- **The Trace Minerals**

If you could remove all of the trace minerals from your body, you would have only a bit of dust, hardly enough to fill a teaspoon. You would also die instantly. Although present in tiny quantities, each of the trace minerals performs some vital role for which no substitute will do. A deficiency of any of them may be fatal, and an excess of many is equally deadly. Remarkably, the way you eat and the way your body handles these minerals enables you to maintain a supply that is just sufficient for health and below the toxic level.

Laboratory techniques developed in the past few decades have enabled scientists to detect the minute quantities of trace minerals in living cells for the first time. Study of the "new" trace elements, using animals, is one of the most active areas of research in nutrition today. An obstacle to determining the precise role of a trace element lies in the nearly impossibly task of providing an experimental diet devoid of that element. Even the dust in the air or the residue left on laboratory equipment by the rinsing water may contaminate the feed enough to prevent a deficiency. Thus research in this area is limited to the study of small laboratory animals, which can be fed highly refined, purified diets in an atmosphere free of all contamination.

The best-known trace elements – iron, iodine, and zinc – have been so thoroughly studied that we can describe many of their roles with certainty. Government authorities have established recommended daily intakes for these three. For six others, the Committee on RDA published tentative ranges for safe and adequate daily intakes for the first time in 1980. Five others are known to be essential nutrients, but the amounts needed are so tiny that they have not yet been measured. Many others are presently under study to determine whether they too perform indispensable roles in the body.

Whole books have been published just on the trace minerals. In selecting the information to present in this session we have chosen to give most attention to those that are likely to have the greatest impact on your health. Iron, for example, is often deficient in the diets of people the world over, and an iron deficiency profoundly hurts the quality of life. Iodine is easy to obtain in adequate amounts, but simple ignorance can precipitate a deficiency, with tragic and irreversible consequences. Until recently, zinc deficiencies were unheard of, but now we know they are present in many of the world's people. New knowledge of equal importance is coming to light about many of the other trace elements. An acquaintance with a few facts presented in this session should enable you to select a diet composed of protective foods that will ensure adequacy for all the essential nutrients.

Iron

Iron is a problem nutrient for millions of people. If you want to plan and consume a diet adequate in iron, you must be well informed.

Iron in the Body

Iron is found in every cell, not only of the human body but also of all-living things, both plant and animal. It occurs in many vital proteins, including those involved in cell respiration and DNA synthesis, and is part of many major enzymes.

Most of the iron in the body is a component of the protein hemoglobin and myoglobin. Both these proteins carry oxygen and release it. Hemoglobin is the oxygen carrier in the red blood cells, and myoglobin is the oxygen carrier in the muscle cells. Myoglobin has a greater holding capacity for oxygen and so serves as a reservoir; its presence in the muscle cells seems to draw oxygen into them. The muscle cells use this oxygen as the receiver for used-up carbon and hydrogen atoms flowing down the glucose-to-energy pathway. These atoms combine to make carbon dioxide and water, the final waste products of metabolism. Thus oxygen keeps the energy-yielding pathway open so that the muscles can remain active. As the muscles use up and excrete their oxygen (combined with carbons and hydrogens), the red blood cells shuttle between muscles and lungs to maintain fresh supplies.

The average red blood cell lives about four months. When it has aged and is no longer useful, it is removed from the body by the spleen and liver cells, which take it apart and prepare many of the degradation products for excretion. The liver saves its iron, however, and attaches it to a protein carrier, which returns it to the bone marrow. The bone marrow, in turn, constantly produces new red blood cells. Thus, although red blood cells are born, live, and die within a four-month cycle, the iron in the body is recycled through each new generation. Only tiny amounts of iron are lost, principally in urine, sweat, shed skin, and (if bleeding occurs), in blood.

About 80 percent of the iron in the body is in the blood, so iron losses are greatest whenever blood is lost. For this reason, "women need more iron," as a well-known television commercial proclaims. Menstruation incurs losses that make a woman's iron needs nearly twice as great as a man's, but anyone who loses blood loses iron.

To help obtain iron, the body provides special proteins to absorb it from food and carry it to the liver, bone marrow, and other blood-manufacturing sites. Iron absorbed through the intestinal cells from food is captured by a blood protein, transferrin that carries it to tissues throughout the body. Each tissue takes up the amount of iron that it needs. The bone marrow and liver take large quantities, other tissues take less. In a pregnant woman, the placenta is avid for iron, delivering large quantities to the fetus even if this means depriving the mother's tissues of iron. Should there be a surplus, special storage proteins in the bone marrow and other organs store it.

Iron clearly is the body's gold, a precious mineral to be hoarded and closely guarded. The number of special provisions for its handling show how vital it is. At the receiving end, in the intestines, another provision shows this even more clearly. Normally only about 10 percent of dietary iron is absorbed. But if the body's supply is diminished or if the need increases for any reason, absorption increases. More transferrin (the carrier that picks up iron from the intestines) is produced so that more than the usual amount of iron can be absorbed.

If absorption cannot compensate for a reduced supply and stores are used up, the red cells become depleted. Then anemia sets in. The most common tests for iron deficiency are measures of the number and size of the red blood cells and of their hemoglobin contents. But before these levels fall, at the very beginning of an iron deficiency, the transferrin concentration rises. A sensitive test that will detect a developing iron deficiency before it is full-blown measures the amount of transferrin in the blood and the amount of iron it is carrying. Technically, this method is known as measuring the total iron-binding capacity (TIBC) and the transferrin saturation.

Hemoglobin
The oxygen-carrying protein of the red blood cells.
Hemo = blood
Globin = globular protein

Myoglobin
The oxygen-carrying protein of the muscle cells
Myo = muscle

Transferrin (trans-FURR-in)
The body's iron-carrying protein.

Mucosal Block
Iron can also lodge in the mucosal cells and end up being excreted from the body.

Storage Proteins
The storage proteins are ferritin (FAIR-I-tin) and hemosiderin (heem-oh-SID-er-in).

Caution:
For women only: you are often told that you need more iron, yet you may often have had your blood cell count or hemoglobin level pronounced normal. Does this mean that you don't need more iron? Not necessarily. The difference between you and the men you know is a difference in your body stores of iron, which doesn't show up in these tests. Most men eat more food than women do, because they are bigger, and so their iron intakes are higher. Besides, women menstruate, and so their iron losses are greater. These two factors – lower intakes and higher losses – may put you much closer to the borderline of deficiency. Even though you may never have been diagnosed as iron-deficient, you are likely to be deficiency-prone. Should you lose blood for any reason (even by giving a blood donation) or become pregnant (so that your blood volume would need to increase), you would need to pay special attention to your diet in an effort to maintain your iron stores. The information about iron in foods, which appears later in this session, is especially important to you.

Iron-Deficiency Anemia
If iron stores are exhausted, the body cannot make enough hemoglobin to fill its new red blood cells. Without enough hemoglobin, the cells are small. Since hemoglobin is the bright red pigment of the blood, the skin of a fair person who is anemic may become noticeably pale. In a dark-skinned person, this symptom can be observed by looking in the corner of the eye. The eye lining, normally pink; will be very pale, even white. A sample of iron-deficient blood examined under the microscope shows smaller cells that are a lighter red than normal. The undersized cells can't carry enough oxygen from the lungs to the tissues, so energy release in the cells is hindered. Every cell of the body feels this effect; the result is fatigue, weakness, headaches, and apathy.

Long before the mass of the red blood cells is affected, however, a developing iron deficiency may affect other body tissues, including the brain. As researchers have become better acquainted with iron, they have learned that it plays roles in the brain not earlier appreciated. For example, iron works with an enzyme that helps to make neurotransmitters, the substances that carry messages from one nerve cell to another. Children deprived of iron show some psychological disturbances, such as hyperactivity, decreased attentiveness, and even reduced IQ. These symptoms are among the first to appear when the body's iron level begins to fall and among the first to disappear when iron intake is increased again.

A curious symptom seen in some iron-deficient subjects is an appetite for ice, clay, paste, and other nonnutritious substances. Such people have been known to eat as many as eight trays of ice in a day, for example. This behavior has been observed for years, especially in women and children of low-income groups who are deficient in either iron or zinc, and has been given the name pica. Pica clears up dramatically within days after iron is given, long before the red blood cells respond.

Muscle tissue, too, is sensitive to depletion of iron stores. By the time the stores are exhausted, work capacity begins to be profoundly affected. One study has shown this especially clearly. As women's hemoglobin levels fell from normal to half of normal, their work capacity declined in proportion. At the lowest level they were unable to do much work at all.

Microcytic (my-cro-SIT-ic) Hypochromic (high-po-KROME-ic) Anemia

This is iron-deficiency anemia.
Micro = small
Cytic = cells
Hypo = too little
Chrom = color

Pica (PIE-ka)

A craving for nonfood substances. Also known as geophagia (gee-oh-FAY-gee-uh) when referring to clay eating.
Picus = woodpecker or magpie
Geo = earth
Phagein = to eat

<u>Caution:</u>
Many of the symptoms described here are easily mistaken for "mental" symptoms. A restless child who fails to pay attention in class might be thought contrary. An apathetic homemaker who has let her housework pile up might be thought lazy. But the possibility is real that both these persons' problems are nutritional.

No responsible nutritionist would ever claim that all mental problems are caused by nutrient deficiencies. But poor nutrition is always a possible cause or contributor to problems like these. When you are seeking the solution to a behavioral problem it makes sense to check the adequacy of the diet and to have a routine physical examination before undertaking more expensive and involved diagnostic and treatment options.

It is conventional to measure the body's iron status by measuring the amount of hemoglobin (in grams per 100 milliliters of blood). The normal level is considered 14 to 15 grams per 100 milliliters for adult men, 13 to 14 for women. Yet many people who have values lower than this have no obvious symptoms. U.S. blacks have average values about half a gram lower than these; it is not known whether this is a genetically determined characteristic or is due to insufficient iron intakes. Some women have no symptoms of anemia – at least as measured by the performance of mental tasks – at levels as low as 10 or even 8 grams. Doubtless people vary; one many may feel miserable with a hemoglobin level of 12 grams; another may feel no effects at a drastically low level of, say, 6 grams: "Who, me? Anemic?" Still, such symptoms as fatigue, weakness, and the like are often seen at levels not much below the standards.

When hemoglobin begins to fall, it is a sign that a long period of depletion of body stores has already occurred. In view of this fact and in light of the behavioral effects of mild iron deficiency in children, it seems reasonable to try to achieve and maintain "normal" hemoglobin levels for the general population: 14 to 15 for men, 13 to 14 for women. Values much below these represent a real hazard to health and to the quality of life.

Norms for Children

Ages 2-5: 11-g/100 ml
Ages 6-12: 11.5 g/100 ml

Note that hemoglobin is measured in grams per 100 milliliters, but we just use the number alone in speaking of it: "Hemoglobin, 14."

Caution:
A low hemoglobin level may represent a dietary iron deficiency, and if it does, the doctor may prescribe iron supplements. But the cause of an iron deficiency may be something else. For example, a vitamin B_6 deficiency can indirectly cause anemia, because vitamin B_6 is required to make the iron-containing portion of the hemoglobin molecule. A vitamin E deficiency can cause anemia by making the red blood cells membranes so fragile that the cells lose their hemoglobin. A folacin deficiency can cause it, because this vitamin is used in making new red blood cells to replace the old ones as they die. A vitamin B_{12} deficiency can cause it, because folacin can't work without B_{12}. A vitamin C deficiency can cause it by reducing the absorption of iron. Vitamin A, too, is involved in the making of red blood cells, and some people's low hemoglobin levels can be corrected only by administering vitamin A. Then there's the mineral copper, which we will discuss later in the session.

Feeling fatigued, weak, and apathetic is a sign that something is wrong but does not indicate that you should take iron supplements. It indicates that (you guessed it!) you should consult your doctor. The doctor herself must use all her knowledge to diagnose correctly the primary cause of a secondary anemia; you don't have a chance at making this kind of diagnosis. In fact, taking iron supplements may be the worst possible thing you could do, because they may mask a serious medical condition, such as hidden bleeding from cancer or an ulcer. Once again – the caution deserves repeating – don't self-diagnose.

However, the role of all these nutrients in making and maintaining red blood cells dictates a preventative measure – eat right! A study of over 200 older adults in Boston provides evidence to support this recommendation. These people all had moderately low hemoglobin levels (below 13) to begin with. Two-thirds were given iron-fortified foods; the other third received the same foods without added iron. At the end of the study, all had higher hemoglobin levels. Food made the difference with or without added iron.

Secondary Nutrient Deficiency
One caused indirectly – not by inadequate intake but by the deficiency of another nutrient, interference with absorption, disease, or other causes.

By these criteria, iron-deficiency anemia is a major health problem in both the United States and Canada and even more so in the rest of the world. It is especially common in older infants, children, women of childbearing age, and people in low-income and minority groups. The incidence of iron-deficiency anemia in these groups ranges from 10 to over 50 percent. It tends to cluster with indicators of low socioeconomic status, such as family instability, little money spent on food, little attention given to children. But no segment of society is free of iron-deficiency anemia, and these groups are not the only ones affected. For example, 1 out of every 20 Canadian men is at moderate risk (hemoglobin 12 to 14), and 1 out of every 100 is at high risk (hemoglobin below 12). Moreover, some subjects with normal hemoglobins are iron deficient by more sensitive tests.

Iron Overload
Iron toxicity is rare but not unknown. The body protects itself against absorbing too much iron by setting up a "block" in the intestinal cells. Proteins trap extra-absorbed iron and hold it until it can be shed from the body when the mucosal cells are shed. The average life of an intestinal cell is only three days; so this method promptly removes excess iron from the system. Still, the mucosal block can be overwhelmed, and iron overload is the result.

Two kinds of iron overload are known. One is caused by a hereditary defect, the other by ingesting too much iron. Tissue damage, especially to the liver, occurs in both, and infections are likely because bacteria thrive in iron-rich blood. Tissue damage is most severe in those who also drink large quantities of alcohol, because alcohol not only damages the liver but also increases the absorption of ferric iron. Certain wines (especially red wines) contain substantial amounts of iron; so the overconsumption of wine is particularly risky. Detection of iron overload is best accomplished by measuring the serum ferritin level, which reflects the body'' total iron stores.

Iron overload is more common in men than in women. An argument against the fortification of foods with iron to protect women is that it might put more men at risk of overload. Indeed, there is some evidence from Sweden, where foods are generously fortified with iron, that this measure has increased the incidence of iron overload in men. It is too bad that a measure meant to promote the health of one sex might put the other at risk.

The ingestion of massive amounts of iron can cause sudden death. The second most common cause (after aspirin) of accidental poisoning in small children is ingestion of iron supplements or vitamins with iron. As few as 6 to 12 tablets have caused death in a child. A child suspected of iron poisoning should be rushed to the hospital to have his stomach pumped; 30 minutes may make a crucial difference.

Mucosal Block to Iron Absorption
The provision of binding proteins (ferritin and a transferrin-like protein) in the mucosal cells to capture and hold unneeded iron to be shed with the cells.

Iron Overload
Toxicity from iron overdose

Hemochromatosis (heem-oh-crome-a-TOCE-iss)
Iron overload characterized by deposits of iron-containing pigment in many tissues, with tissue damage. Hemochromatosis is a hereditary defect in iron metabolism.

Hemosiderosis (heem-oh-sid-er-OH-sis)
Iron overload characterized by excessive iron deposits in hemosiderin, the normal iron-storage protein.

Recommended Intakes of Iron:
Men: 10 mg/day
Women (Canada): 14 mg/day
Women (U.S.): 18 mg/day

How recommended daily intake for iron is calculated (for example, for an adolescent girl):

Losses from urine and shed skin: 0.5 to 1.0 mg
Losses through menstruation (about 15-mg total averaged over 30 days): 0.5 mg

Net for growth:
Average daily needs (total): 1.5 to 2.0 mg

Only 10 percent of ingested iron is absorbed, so this girl must ingest 15 to 20 mg per day.

Heme (HEEM)
About 40 percent of the iron in meat, fish, and poultry is bound into molecules of heme, the iron-holding part of the hemoglobin and myoglobin proteins. Heme iron is much more absorbable (23 percent) than nonheme iron. Meat, fish, and poultry also contain a factor ("MFP factor") other than heme that promotes the absorption of iron, even of the iron from other foods eaten at the same time as the meat.

Milk Anemia
Overconsumption of milk is a common cause of iron deficiency in children; the resulting anemia is known as milk anemia.

Iron in Foods
The usual Western mixed diet provides only about 5 to 6 milligrams of iron in every 1,000 kcalories. The recommended daily intake for an adult man is 10 milligrams, and most men require more than 2,000 kcalories; so a man can easily meet his iron needs without special effort. The recommendation for a woman, however, is 14 to 18 milligrams per day. Because women typically consume fewer than 2,000 kcalories per day, they understandably have trouble achieving this intake. A woman who wants to meet her iron needs from foods must increase the iron-to-kcalorie ratio of her diet so that she will receive about double the average amount of iron – at least 10 milligrams per 1,000 kcalories. This means she must emphasize the most iron-rich foods in every food group.

Several factors influence the absorption of iron significantly enough so that they have to be considered by anyone who wants to know how much iron a person really gets from a meal.

The average amount of iron absorbed is 10 percent, but up to 40 percent of the iron in meat, fish, poultry, and soybeans may be absorbed. Less than 10 percent of the iron in eggs, whole grains, nuts, and dried beans is absorbed. At the bottom of the list is spinach; only 2 percent of its iron is absorbed. The iron from iron supplements, too, is absorbed at a rate of only about 2 percent. Vitamin C eaten with any iron source doubles or triples the amount of iron absorbed (except heme iron). Obviously, then, a woman who includes some meat in everyday meal planning will get a head start toward meeting her iron needs, especially if she makes periodic use of liver and other organ meats.

Foods in the milk group are notoriously poor iron sources, as poor in iron as they are rich in calcium. Although these foods are an indispensable part of the diet, they should not be overemphasized. In considering the grain foods, remember that iron is one of the enrichment nutrients. Whole-grain or enriched breads and cereals – not refined, unenriched pastry products – are the best choices, and the more of them you eat, the more iron you receive. Finally, among other plant foods, the legume family, the dark greens, and dried fruits are the most iron rich. A set of guidelines, then for planning an iron-rich diet is as follows:

- **Milk and Cheese**: Don't overdo foods from the milk group (but don't omit them either; you need them for calcium). Drink skim milk to free kcalories to be invested in iron-rich foods.

- **Meat**: Use liver and other organ meats frequently, perhaps every week or two. Meat, fish, and poultry are excellent iron sources.

- **Meat Substitutes**: Don't forget legumes. A cup of peas or beans can supply up to 5 milligrams of iron.

- **Breads and Cereals**: Use only whole-grain, enriched, and fortified products.

- **Vegetables**: The dark-green leafy vegetables are rich in iron. Eat vitamin C-rich vegetables often to enhance absorption of the iron from foods eaten with them.

- **Fruits**: Dried fruits like raisins, apricots, peaches, and prunes are high in iron. Eat vitamin C-rich fruit often with iron-containing foods.

Knowledgeable cooking and menu planning can enhance the amount of iron delivered by your diet. The iron content of 100 grams of spaghetti sauce simmered in a glass dish is 3 milligrams, but it's 87 milligrams when the sauce is cooked in an iron skillet. Even in the short time it takes to scramble eggs, you can triple their iron content by cooking them in an iron pan. Admittedly, the absorption of this iron is poor, but every little bit helps. Therefore, an additional suggestion is:

- Cook with iron skillets whenever possible.

Even after taking all these precautions, a woman may not accumulate enough storage iron to prepare her for the increased demands of pregnancy and childbirth. In 1974 the Committee on RDA acknowledged for the first time that pregnant women might need supplemental iron. The Canadian Dietary Standard also includes this statement. However, since the iron from supplements is far less well absorbed than that from food, the doses have to be as high as 50 milligrams per day. Absorption of iron from supplements is improved when they are taken with meat or with vitamin C-rich foods or juices.

The use of fortified foods is another option. Some breakfast cereals boast that they contain 100 percent of the recommended daily intake of iron. These may indeed boost the day's iron intakes, even though absorption of their iron is poor. A number of proposals have been made for further fortification. Canada has considered adding iron to milk; other ideas are to add it to coffee, to junk foods, even to salt. At present, 25 percent of all the iron consumed in the United States derives from fortified foods. A proposal to increase the iron level in enriched bread above that now prescribed by FDA regulations has been defeated. Ultimately, it is up to the consumer herself to see that she gets enough iron.

Enrichment
The addition of iron, thiamin, riboflavin, and niacin to refined grain products to restore approximately their original contents.

Fortification
The addition of nutrients to a food – but not necessarily the nutrients that were originally found there.

Zinc
Ten years ago, zinc was hardly known as a nutrient to the man on the street. In 1974, it appeared in the RDA tables for the first time, and today it is often added to vitamin-mineral supplements. Research on zinc has expanded to hundreds of articles.

Zinc in the Body
Zinc appears in every body tissue but is distributed unevenly. The adult human body contains 2 to 3 grams of zinc. The highest concentrations are in the eye, liver, kidney, muscle, skin, bones, and male reproductive organs. Zinc is tightly tied up in tissues such as the skin, hair, and bones and so is unavailable to the rest of the body except when tissue or bone breaks down. Zinc must therefore by provided relatively regularly in the diet.

Zinc supports several physiological functions. Most importantly, there are now over 70 known enzymes, which require zinc as a cofactor. Zinc occurs at the active site, maintains the structural integrity of the protein, and may also facilitate the enzyme's catalytic activity by lowering the amount of energy necessary to get it started.

Zinc works with proteins in every corner of the body. It is necessary for normal metabolism of protein, carbohydrate, fat, and alcohol. It is associated with the hormone insulin in the pancreas. It is involved in the synthesis of DNA and RNA, cell replication, immune reactions, the cells' production and disposal of carbon dioxide, utilization of vitamin A, taste perception, wound healing, the making of sperm, and the development of the fetus.

Absorption of zinc is known to occur in the upper intestine, but a complete description of this process has not yet been derived from research. Zinc is evidently pulled (by active transport) into cells even when its concentration is higher inside them than outside. Absorption is aided by a small molecule, whose exact nature is disputed.

After zinc has entered a cell lining the intestine, it may become involved in the metabolic functions of the cell itself or pass through the far side of the cell into the portal blood. The absorbed zinc may also become trapped within the cell by a special binding protein similar to the one described earlier for iron.

As for iron, a homeostatic mechanism seems to be at work to regulate the amount of zinc entering the body. Extra zinc (or iron) is held within the intestinal cell and only the amount needed is released into the bloodstream. The zinc status of the individual influences the percentage of zinc absorbed from the diet; if more is needed, more is absorbed. Cells are shed daily from the intestinal lining and are excreted in the feces; they carry the zinc they have retained out of the body with them.

Zinc circulating within the body is taken up by liver cells and is bound to a protein inside them (liver metallothionein). The amount bound depends on the amount of circulating zinc. Zinc circulates in the body until the concentration in and around liver cells reaches a certain threshold. Then any additional zinc is packaged with liver metallothionein.

While traveling in the bloodstream, zinc is transported by proteins. Plasma proteins such as albumin, transferrin, and others may bind significant amounts of zinc. The significance of the involvement of either transferrin or albumin with zinc transport is complex. Anything that leads to a decrease in plasma albumin – for example, pregnancy or malnutrition – would lower plasma zinc levels as well. Anything that binds transferrin might also hinder zinc absorption. In normal individuals, transferrin is usually less than 50 percent saturated with iron, but in cases of iron overload, it is more saturated. Iron excess thus leaves too few binding sites available, thereby causing an impairment of zinc absorption.

An interesting phenomenon in zinc nutriture is the cycling of zinc in the body. The intestine actually receives two doses of zinc with each meal – one from ingested foods and the other from the zinc-rich pancreatic secretions. Thus even zinc that has already entered the body is rescreened periodically by the intestine and can be refused entry or tied up in intestinal cells on any of its times around.

Excretion of zinc occurs primarily by way of the feces, which contain both unabsorbed zinc and zinc from the pancreatic juices. Some zinc is also lost in the urine. Alcohol abuse increases urinary losses of zinc. An increase in muscle catabolism, as in fasting, injury, or surgery, also incurs urinary losses of zinc. Free dietary amino acids such as histidine or cysteine can bind zinc, and thus cause losses. People who take supplements of amino acids to help their health may therefore actually by harming it by interfering with their zinc absorption.

Other losses of zinc occur in sweat, hair, menstrual blood, seminal fluid, and human milk. Studies of all these losses added together have enabled researchers to estimate the human requirement for zinc.

Cofactor
A mineral element that works with an enzyme, facilitating the enzyme's action.

Zinc-Binding Ligant (LYE-gand) (ZBL)
The small molecule that assists in zinc absorption.

Metallothionein (meh-TAL-oh-THIGH-oh-neen)
The binding protein for zinc is a sulfur-rich protein.
Metallo – containing a metal
Thio – containing sulfur
Ein – a protein

Zinc Deficiency and Toxicity

A deficiency of zinc in humans was first reported in the 1960s from studies with growing children and adolescent males in Egypt, Iran, and Turkey. The native diets were typically low in animal protein and high in whole grains and beans; consequently they were high in fiber and phytates. The zinc deficiency was marked by dwarfism or severe growth retardation and arrested sexual maturation – symptoms that were responsive to zinc supplementation. Conditions other than diet which contribute to development of zinc deficiency, include loss of blood due to parasitic infections, climates that increase sweat losses, and clay eating.

Since the reports of the 1960s, cases of zinc deficiency have been discovered closer to home, in U.S. schoolchildren. A number of Denver children had low hair zinc levels, poor growth, poor appetite, and decreased taste sensitivity. The children were described as "picky eaters" and ate less than an ounce of meat per day. A recommendation from these observations might be that when poor growth is accompanied by poor appetite, the pediatrician should evaluate the child's zinc status.

Reports of the role of zinc in wound healing are controversial. It appears that in individuals with normal zinc status, zinc has no effect on wound healing. Healing appears to be delayed, however, in persons with zinc deficiency. Zinc is known to be required in collagen synthesis, and the skin is rich in zinc.

An intriguing example of the many nutrient-nutrient interactions in human nutrition is the case of zinc and vitamin A. Zinc is required for the synthesis of retinol-binding protein, RBP. RBP, in turn, is necessary for mobilization of vitamin A from the liver. A zinc deficiency may therefore cause an apparent vitamin A deficiency, because plasma levels of vitamin A will remain low even though there is plenty of vitamin A stored in the liver.

Zinc deficiency in humans appears to be related to abnormal rod function and impaired visual adaptation to darkness. Zinc is necessary for the reaction that produces the active form of vitamin A (retinal) necessary to form rhodopsin, the rods' visual pigment.

Zinc is a relatively nontoxic element. However, it can be toxic if consumed in large enough quantities. Accidental consumption of high levels of zinc may cause vomiting, diarrhea, fever, exhaustion, and a host of other symptoms. Large doses can even be fatal. See the table below for the areas affects and main effects of those areas.

Toxicity from ingestion of zinc could occur from misuse of supplements. Also, acidic foods or drinks which have been allowed to stand for long periods of time in galvanized containers may contain toxic levels of this trace mineral. Remember, too, that a large amount of one trace element may induce a deficiency of another. Such is the relationship between zinc and copper. Excess zinc intake may also interfere with the intestinal absorption of calcium, due to competition between the two elements for common intestinal binding sites.

By now, you can guess what populations might be at risk for developing inadequate zinc status. Primarily, they are people who are growing – infants, children, teenagers, and pregnant women. Pregnant teenagers are at particular risk, because they need zinc for their own ongoing growth as well as for the developing fetus. Persons on limited food intakes, such as those on weight control regimens, may also be at risk. A warning of those following very low kcalories or starvation diets – they cause not only a low zinc intake but also a loss of zinc from body tissues being broken down as a source of energy. The elderly may also have limited food intakes due to socioeconomic factors. Hospital patients with decreased appetite or receiving improperly formulated tube feedings are also at risk. Certain drug therapies may also interfere with zinc absorption.

The diets of vegetarians, especially pregnant vegetarians, who consume large amounts of fiber, phytate, and dairy foods or low levels of protein, need to be scrutinized for possible zinc deficiency. Populations dependent on food stables or cultural foods high in phytate and fiber content need to be evaluated as well for zinc status.

Recommended Intake of Zinc

Adults (U.S.): 15 mg/day
Men (Canada): 10 mg/day
Women (Canada): 9 mg/day

Phytate or Phytic Acid

Is a storage compound found in plant seeds. Phytic acid is concentrated in the husks of grains, legumes, and seeds, and is capable of binding zinc in an insoluble complex in the intestine. Phytate binds not only zinc but also other positive ions such as calcium, magnesium, copper, and iron.

Zinc Toxicity

Area Affected	Main Effects
Blood	Anemia; reduced hemoglobin production
Bone	Growth depression
Digestive System	Diarrhea; vomiting; decreased calcium and copper absorption
Immune System	Fever; elevated white blood cell count
Kidney	Renal failure
Muscle	Muscular pain and uncoordination
Nervous System	Nausea; exhaustion; dizziness; drowsiness
Reproductive System	Reproductive failure

Clay Eating (pica or geophagia)

Occurs among the poor in rural areas of the Middle East, and has also been noted in the rural South in the United States. The clay acts to bind zinc (as well as iron) by attracting these positively charged ions, making them unabsorbable in the intestine.

Galvanized

Term referring to metal containers that have been treated with a zinc-containing coating to prevent rust.

Zinc in Foods

The daily recommended intake of zinc is about 10 to 15 milligrams. This figure assumes that 40 percent of dietary zinc is available to the body, although, as we shall see later, this is not always the case. Requirements for infants and children are relatively high due to the role of zinc in normal growth and development.

An average 1,500-kcalorie diet provides about 6.3 milligrams of zinc per day, or about 40 percent of the RDA. Zinc is highest in foods of high protein content, such as shellfish (especially oysters), meats, and liver. As a rule of thumb, two ordinary servings a day of animal protein will provide most of the zinc a healthy person needs. Milk, eggs, and whole-grain products are good sources of zinc if large quantities are eaten. For the infant, breast milk is a good source of zinc, which is easier to absorb from human milk than from cow's milk. Vegetables, fresh or canned, vary in zinc content depending on the soil in which they are grown. The zinc content of cooking water varies from region to region as well.

Besides the zinc content of foods, many dietary factors affect the absorption of zinc. The refining of grains lowers their zinc content. Galvanized cooking pots, in earlier times, contributed zinc to foods, especially to acid foods, but with the increased use of stainless steel and plastic utensils to prepare and store food, this source of zinc is no longer significant.

Factors interfering with the availability of zinc for absorption include phytic acid, calcium, phosphorus, and fiber. Complexes with phytate become even more insoluble in the presence of calcium and phosphorus, as when people consume dairy foods. Calcium facilitates the binding of both zinc and copper to phytic acid. Zinc also forms insoluble complexes with some plant fibers. Therefore, a high-fiber diet may lead to a deficiency of zinc, especially if zinc is already in short supply.

Both phytic acid and fiber are prevalent in plant foods. As you might suspect, then, concern about the bioavailability of dietary zinc is increasing as more and more persons tend toward vegetarianism and higher fiber intakes. The plant foods highest in zinc, such as peanuts, cooked dried beans, and wheat germ, may not be able to nourish the body as effectively as animal foods because of their phytate and fiber content. Foods need to be selected carefully, not only for mineral content but also for mineral availability, so that vegetarian and high-fiber diets will supply the essential minerals in sufficient quantities to meet people's metabolic needs.

The process of baking bread usually includes the step of yeast fermentation. Enzymes produced by yeasts destroy phytate; thus helping make the zinc available for absorption. It is thought to be beneficial, when making whole-grain breads, to extend this period of fermentation.

In Middle Eastern countries where zinc deficiency has been reported, a common food staple is unleavened whole-grain bread. Without the fermentation process, the zinc availability from these breads is poor. The Whole Health Organization has suggested that intake recommendations for zinc be on a sliding scale based on the estimated biological availability of the mineral from various regional diets.

The presence of competing ions – cadmium, lead, mercury, arsenic, copper, and calcium – also influences zinc status. The reverse is also true; in fact, in the future, zinc may be used to compete with metals such as lead to reduce their toxicity. With regards to copper, a high zinc intake is known to produce symptoms of copper deficiency such as anemia.

<u>Caution:</u>

Whole-grain breads and cereal contain zinc, but they also contain phytate and fiber. Refined breads and cereals are stripped of their phytate and fiber, but they also contain less zinc. Which is a better zinc source – the whole grain or the refined product? The answer has to do with the numbers of molecules of zinc and zinc-binder present in the grain. If 100 molecules of zinc are present together with 50 zinc-binding molecules, then 50 of the zinc molecules may be bound but the other 50 will be available for absorption. Whole grains contain phytate and fiber, yes, but they contain relatively more zinc, enough so that the excess zinc is greater per serving of whole-grain bread than the amount available from a comparable serving of refined bread. Thus even though whole grains do contain some bound, unavailable zinc; they are still preferred to refined products as a zinc source. Food research in the future will ask, not how much zinc or how much zinc binder is present in the food but how much zinc relative to the amount of binder – or better still, how much available zinc.

This example illustrates a principle that may well have occurred to you many times as you read earlier sessions. Nutrition "facts" are often more complicated than they may seem at first. You might remember this the next time someone tries to sell you something on the basis of an oversimplified statement. Always ask, "Is he telling the whole story?"

Iodine

Iodine occurs in the body in an infinitesimally small quantity, but its principal role in human nutrition is well known and the amount needed is well established. Iodine is part of the thyroid hormones, which regulate body temperature, metabolic rate, reproduction, growth, the making of blood cells, nerve and muscle function, and more. The hormones enter every cell of the body to control the rate at which the cells use oxygen. This is the same as saying that thyroxin controls the rate at which energy is released.

Iodine must be available for thyroid hormones to be synthesized. The amount in the diet is variable and generally reflects the amount present in the soil in which plants are grown or on which animals graze. Iodine is plentiful in the ocean, so seafood is a dependable source. In the United States, in areas where the soil is iodine-poor (most notably the Plains states), the use of iodized salt has largely wiped out the iodine deficiency that once was widespread.

<u>Caution:</u>

People sometimes wonder whether sea salt, made by drying ocean water, is preferably to purified sodium chloride for use in the salt shaker. Sea salt does contain trace minerals, but it loses its iodine during the drying process. Thus, in a region where goiter is a risk, iodized sodium chloride is the salt to choose.

When the iodine level of the blood is low, the cells of the thyroid gland enlarge in an attempt to trap as many particles of iodine as possible. If the gland enlarges until it is visible, it is called a simple goiter.

Goiter is estimated to affect 200 million people the world over. In all but 4 percent of these cases the cause is iodine deficiency. As for the 4 percent (8 million), they have goiter because they overconsume plants of the cabbage family and others that contain an antithyroid substance whose effect is not counteracted by dietary iodine. The goitrogens present in plants serve as a reminder that food additives may not be such great offenders as some natural components of foods.

In addition to causing sluggishness and weight gain, an iodine deficiency may have serious effects on the development of an infant in the uterus. Severe thyroid undersecretion during pregnancy causes the extreme and irreversible mental and physical retardation known as cretinism. A cretin has an IQ as low as 20 and a face and body with many abnormalities. Much of the mental retardation associated with cretinism can be averted by early diagnosis and treatment.

The iodization of salt in the Plains states eliminated the widespread misery caused by goiter and cretinism in the local people during the 1930s. Once these scourges had disappeared, a new generation of children grew up who never saw the problem and so had no appreciation of its importance. Rejecting iodized salt out of ignorance, they allowed iodine deficiencies to creep back into their lives. Hopefully, now, education is keeping them informed of the need to continue using iodized salt.

The recommended intake of iodine for adults is 100 to 150 micrograms a day, a minuscule amount. Like chlorine, iodine is a deadly poison in large amounts, but the iodide ion, which occurs in foods, is far less toxic, and traces of it are indispensable to life. The need for iodine is easily met by consuming seafood, vegetables grown in iodine-rich soil, and (in iodine-poor areas) iodized salt. In the United States, you have to read the label to find out whether salt is iodized; in Canada all table salt is iodized.

Excessive intakes of iodine can also cause an enlargement of the thyroid gland resembling goiter, which in infants can be so severe as to block the airways and cause suffocation. A dramatic increase in iodine intakes in the United States concerns observers. Average consumption rose from 150 micrograms per day in 1960 to over 450 in 1970, and reached an all-time high of over 800 in 1974; since then it has declined somewhat but still is several times the RDA. The toxic level at which detectable harm results is thought to be over 2,000 micrograms per day for an adult, only a few times higher than current average consumption levels.

Most of the excess iodine seems to be coming from iodates – dough conditioners used in the baking industry – and from milk produced by cows exposed to iodine-containing medications and disinfectants. Now that the problem has been identified, both industries have reduced their use of these compounds, but the sudden emergence of this problem points to a need for continued surveillance of the food supply.

Goiter (GOY-ter)
An iodine-deficiency disease. Goiter caused by iodine deficiency is a simple goiter.

Goitrogen
A thyroid antagonist found in food; caused toxic goiter.

Cretinism (CREE-tin-ism)
An iodine-deficiency disease characterized by mental and physical retardation.

The RDA for iodine
150 ug

Canadian Dietary Standard
140 – 150 ug for men
100 – 110 ug for women

Copper
The body contains about 75 to 100 milligrams of copper, which performs several vital roles. It is part of several enzymes. As a catalyst in the formation of hemoglobin, it helps to make red blood cells. It is involved in the manufacture of collagen and the healing of wounds, and it helps to maintain the sheath around nerve fibers. Most of what is known about copper comes from animal research, which has provided clues about its possible roles in humans. Copper's critical roles seem to have to do with helping iron shift back and forth between its +2 and +3 states. This means that copper is needed in many of the reactions related to respiration and the release of energy.

Copper deficiency is rare but not unknown. It has been seen in children with kwashiorkor and with iron-deficiency anemia and can severely disturb growth and metabolism. Excess zinc interferes with copper absorption and can cause deficiency.

The best food sources of copper include grains, shellfish, organ meats, legumes, dried fruits, fresh fruits, and vegetables – a long list showing that copper is available from almost all foods. About a third of the copper taken in food is absorbed, and the rest is eliminated in the feces.

Estimated safe and adequate daily dietary intake of copper (adults)
2-3 mg

Manganese
The human body contains a tiny 20 milligrams of manganese, mostly in the bones and glands. Still, the represents billions on billions of molecules. Animal studies suggest that manganese cooperates with many enzymes, helping to facilitate dozens of different metabolic processes. Manganese deficiency in animals deranges many systems, including the bones, reproduction, the nervous system, and fat metabolism.

Deficiencies of manganese have not been seen in humans, but toxicity may be severe. Miners who inhale large quantities of manganese dust on the job over prolonged periods show many of the symptoms of a brain disease, with frightening abnormalities of appearance and behavior. "Facial expression is mask-like, the voice monotonous; and intention-tremor, muscle rigidity and spastic gait appear."

Estimated safe and adequate daily dietary intake of manganese (adults)
2.5 – 5.0 mg

<u>Caution:</u>
The example of manganese underlines the fact that toxicity of the trace elements occurs at a level not far above the estimated requirement. Thus it is as important not to overdose as it is to have an adequate intake. The Committee on RDA underscores this point by adding the special warning to its trace-mineral table "not to exceed the upper end of the range of recommended intakes." The National Nutrition Consortium, too, worries that, now that more trace minerals are known, they will be added to vitamin-mineral pills, making toxic overdoses more likely. The FDA is not permitted to enforce limits on the amounts of trace minerals added to supplements; so this is an area in which the consumer himself has to be careful. Beware of supplements containing trace minerals. It is safer to consume a diet that provides foods from a variety of sources than to try to put together, without causing toxicity, a combination of pills that will meet all your needs.

Fluoride
Only a trace of fluoride occurs in the human body, but studies have demonstrated that where diets are high in fluoride, the crystalline deposits in bones and teeth are larger and more perfectly formed. When bones and teeth become calcified, first a crystal called hydroxyapatite is formed from calcium and phosphorus. Then fluoride replaces the hydroxy (OH0 portions of the crystal, rendering it insoluble in water and resistant to decay.

Drinking water is the usual source of fluoride, although fish and tea may supply substantial amounts. Where fluoride is lacking in the water supply, the incidence of dental decay is very high. Dental problems can cause a multitude of health problems, affecting the whole body. Fluoridation of community water where needed, to raise its fluoride concentration to one part per million (1 ppm), is thus an important public health measure. Fluoridation of community water is presently practiced in more than 5,000 communities across the United States, and about 100 million people are drinking it.

In some communities the natural fluoride concentration in water is high, 2 to 8 ppm, and children's teeth develop with mottled enamel. This condition, called fluorosis, may not be harmful (in fact, these children's teeth may be extraordinarily decay-resistant), but violates the prejudice that teeth "should" be white. Fluorosis does not occur in communities where fluoride is added to the water supply.

Not only does fluoride protect children's teeth from decay, but also it makes the bones of older people resistant to adult bone loss (osteoporosis). Fluoride is also required for growth in animals and is an essential nutrient for humans; in fact, the continuous presence of fluoride in body fluids is desirable. Luckily, all normal diets include fluoride. It is toxic in excess, but toxicity symptoms appear only after chronic intakes of 20 to 80 milligrams a day over many years. The amount consumed from fluoridated water is typically about 1 milligram a day. Despite its value, violent disagreement often surrounds the introduction of fluoride to a community.

People whose water supplies do not contain adequate fluoride need to find alternative means of protecting their children's teeth. The best temporary solution seems to be to use fluoride toothpastes and/or to have children obtain a fluoride treatment of the surface of their teeth every year. Fluoride tables are also available. For infants there are vitamin drops with fluoride in them, but their effectiveness is limited.

Enamel and Dentin
The outer two layers of the teeth, enamel and dentin, are composed largely of calcium compounds, including hydroxyapatite and fluorapatite.

Hydroxyapatite (high-droxy-APP-uh-tite)
The major calcium-containing crystal of bones and teeth.

Fluorapatite (floor-APP-uh-tite)
The stabilized form of bone and tooth crystal, in which fluoride has replaced the hydroxy groups of hydroxyapatite.

Fluorosis (fleur-OH-sis)
Mottling of the tooth enamel; due to ingestion of too much fluoride during tooth development.
Osis = too much

Estimated safe and adequate daily dietary intake of fluoride (adults)
1.5 – 4.0 mg

Chromium
Experiments on animals have shown that chromium works closely with the hormone insulin, facilitating the uptake of glucose into cells and the release of energy from it. When chromium is lacking, the effectiveness of insulin is severely impaired, and a diabetes-like condition results.

Like iron, chromium can have two different charges. The +3 ion seems to be the most effective in living systems. It also occurs in association with several different complexes in foods. The one that is best absorbed and most active is a small organic compound named the glucose tolerance factor (GTF). This compound has been purified from brewer's yeast and pork kidney and is believed to be present in many other foods. It may be that when more is known, the GTF, rather than chromium, will be dubbed an essential nutrient and classed among the vitamins.

Depleted tissue concentrations of chromium in human being have been linked to adult-onset diabetes and growth failure in children with protein-kcalorie malnutrition. Chromium has also been shown to remedy impaired carbohydrate metabolism in several groups of older people in the United States.

GTF (glucose tolerance factor)
A small organic compound containing chromium.

Estimated safe and adequate daily dietary intake of chromium (adults)
0.05 – 0.20 mg

Selenium
Selenium is a trace element that functions as part of an enzyme. The enzyme acts as an antioxidant and can substitute for vitamin E in some of that vitamin's antioxidant activities.

Selenium deficiency affects the heart. A severe deficiency can cause heart failure; a chronic, mild deficiency enlarges the heart and impairs its function. In some parts of China, selenium deficiency affects hundreds of thousands of children; not until the 1970s, however, was the cause of their heart trouble confirmed and remedied with selenium supplements. The conclusive study of over 36,000 subjects was published in 1980.

The region of China in which Keshan disease is prevalent is a region where the soil and foods are selenium-poor. In other parts of the world, selenium-poor soil has been found to correlate with certain kinds of cancer. The question whether selenium protects against cancer has stimulated research with both animal and human subjects, and it seems possible that dietary selenium adequacy may be one of the many health factors that defend against cancer. Results of research to date have not been clear, however. For example, an attempt was made to show a relationship between blood selenium and breast cancer incidence in women in a selenium-poor area of Oregon, but no such relationship was found. The authors were forced to conclude that there was "no justification at this time for the use of selenium supplements by the people living in this low selenium area."

High doses of selenium are toxic, causing loss of hair and nails, lesions of the skin and nervous system, and possibly damage to the teeth. An outbreak of selenium poisoning arose in China in the 1960s when a local rice crop failed and inhabitants of five villages consumed vegetables from a region where selenium-rich coal contaminated the soil in which the vegetables were grown. Some 50 percent of the villagers became seriously ill before the cause was discovered.

Glutathione Peroxidase
The enzyme of which selenium is a part is glutathione peroxidase, which destroys oxidative compounds that could otherwise oxidize other compounds in the cell.

Keshan Disease
The heart disease caused by selenium deficiency is named Keshan disease, for one of the provinces of China where it was studied.

Estimated safe and adequate daily dietary intake of selenium (adults)
0.05 – 0.20 mg

Molybdenum
Finally, molybdenum has also been recognized as an important mineral in human and animal physiology. It functions as a working part of several metalloenzymes, some of which are giant proteins. One, for

example, contains two atoms of molybdenum and eight of iron. Deficiencies of molybdenum are unknown in animals and humans, because the amounts needed are minuscule – as little as 0.1 part per million parts of body tissue. Excess molybdenum causes toxicity in animals, but this effect has not been seen in humans.

Metalloenzyme
An enzyme that contains one or more minerals as part of its structure.

Estimated safe and adequate daily dietary intake of molybdenum (adults)
0.15 – 0.50 mg

Other Trace Minerals
None of the trace minerals has been known for very long, and some are extremely recent newcomers.

- Nickel is now recognized as important for the health of many body tissues; deficiencies harm the liver and other organs.

- Silicon is known to be involved in bone calcification, at least in animals.

- Tin is necessary for growth in animals and probably in humans.

- Vanadium, too, is necessary for growth and bone development and also for normal reproduction; human intakes of vanadium may be close to the minimum needed for health.

- Cobalt is recognized as the mineral in the large vitamin B_{12} molecule; the alternative name for vitamin B_{12}, cobalamin, reflects the presence of cobalt.

In the future we may discover that many other trace minerals also play key roles: silver, mercury, lead, barium, and cadmium. Even arsenic – famous as the poisonous instrument of death in many murder mysteries and known to be a carcinogen – may turn out to be an essential nutrient in tiny quantities.

As research on the trace minerals continues, many interactions between them are also coming to light. An excess of one may cause a deficiency of another. (A slight manganese overload, for example, may aggravate an iron deficiency.) A deficiency of one may open the way for another to cause a toxic reaction. (Iron deficiency, for example, makes the body much more susceptible than normal to lead poisoning.) Good food sources of one are poor food sources of another; and factors that cooperate with some trace elements oppose others. (Vitamin C, for example, enhances the absorption of iron and depresses that of copper.) The continuous outpouring of new information about the trace minerals is a sign that we have much more to learn.

CERTIFIED HEALTH & NUTRITION COUNSELOR ONLINE COURSE - SESSION 11 **– QUESTION & ANSWERS**

NAME: ____

ADDRESS: ____

PHONE: ____

FAX: ____

E-MAIL: ____

Please be sure to fill out the information above, complete the test and e-mail or fax it back to us at iridology@netzero.net or 425-955-4639. We will grade your question & answer session and will let you know if we have any questions or concerns.

1. Where is iron principally found?

2. Where are new red blood cells synthesized?

3. Iron-deficiency anemia is most common in ______________ and _________________.

4. Name 11 sources of iron-rich foods:

5. Zinc supports which physiological functions in the body?

6. What are the richest food sources of zinc?

7. A deficiency of iodine may cause a _________, ____________________, and _____________.

8. Copper is important for which 3 bodily functions?

9. An overdose of Manganese may cause which severe brain-disease syndrome in humans?

10. Chromium deficiency is believed to be responsible for what disease?

11. A severe deficiency of selenium can cause what?